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DESIGN, DEVELOPMENT AND DEMONSTRATION
OF A
WARM GAS DISTRIBUTION SYSTEM

JPL CONTRACT NO. 951988
QUARTERLY REPORT
PERIOD ENDING 31 DECEMBER, 1967

THIS WEEK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, AS SPONSORED BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION UNDER CONTRACT NAS 7-100

GENERAL ELECTRIC
SPACECRAFT DEPARTMENT
A Department of the Missile and Space Division
Valley Forge Space Technology Center
P. O. Box 8555 • Philadelphia, Penna. 19101

LIST OF CONTRIBUTORS

C.C. Rich	Program Manager
W.D. Boyce	Project Engineer
T.E. Hagan	Manufacturing Procedures
G.D. Edge	Component Test Engineering
G.H. McBride	Component Test Operations

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ABSTRACT

Progress during the second three month period of a program to design, develop, and demonstrate a warm gas distribution system for use with a hydrazine fueled gas generator to provide spacecraft attitude control torques is reported. Activity during this reporting period was concentrated in component manufacture and delivery, and in the manufacture of the system test structure.

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SECTION 1

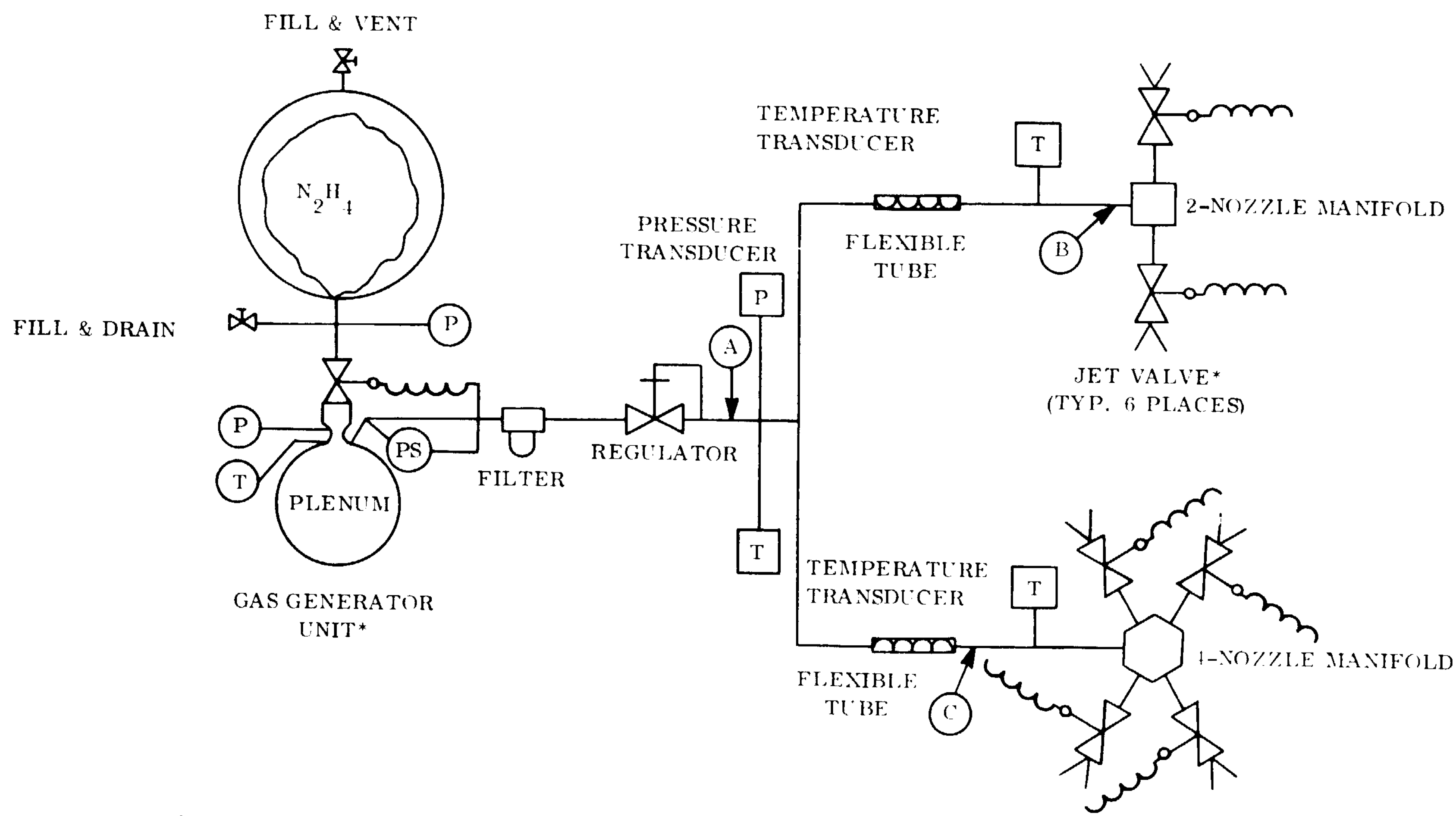
INTRODUCTION

This report covers the second three months (period ending December 31, 1967) of design and development effort performed by General Electric Company, Spacecraft Department, on the Warm Gas Distribution System under JPL Contract No. 951988.

The warm gas mass expulsion system, shown schematically in Figure 1-1, represents an approach to the use of hydrazine in a low thrust mass expulsion attitude control system for long-life earth orbiting and interplanetary type spacecraft.

The gas generator portion of the system (Customer Furnished) consists of a bladder-equipped prepressurized tank for the storage of liquid hydrazine. The hydrazine is expelled from the tank through a solenoid valve to a gas generator consisting of an injector and combustion chamber. The injector, used to promote combustion efficiency and stability, injects the liquid hydrazine into the combustion chamber, which contains a spontaneous catalyst (Shell 405). The catalyst decomposes liquid hydrazine into a gas consisting of ammonia and nitrogen at a temperature of approximately 2500°F. Further dissociation of approximately 60 percent of the ammonia into nitrogen and hydrogen results in an exit gas temperature of approximately 1700°F. These exit gases are stored and cooled in a low pressure plenum which supplies the warm gas distribution system with gases in the temperature and pressure ranges of +30 to +400°F and 50 to 200 psig, respectively. The plenum gas pressure is controlled by a pressure switch which, when sensing an incremental pressure drop, actuates the solenoid valve allowing additional hydrazine to be decomposed and stored.

The General Electric Company, Spacecraft Department, is responsible for the design, development, and demonstration of the Warm Gas Distribution (WGDS) shown by block diagram in Figure 1-2.



*CUSTOMER FURNISHED

LINE LENGTH FROM POINT A TO POINTS B AND C 10 FT

Figure 1-1. Schematic Diagram of Warm Gas Spacecraft Attitude Control System

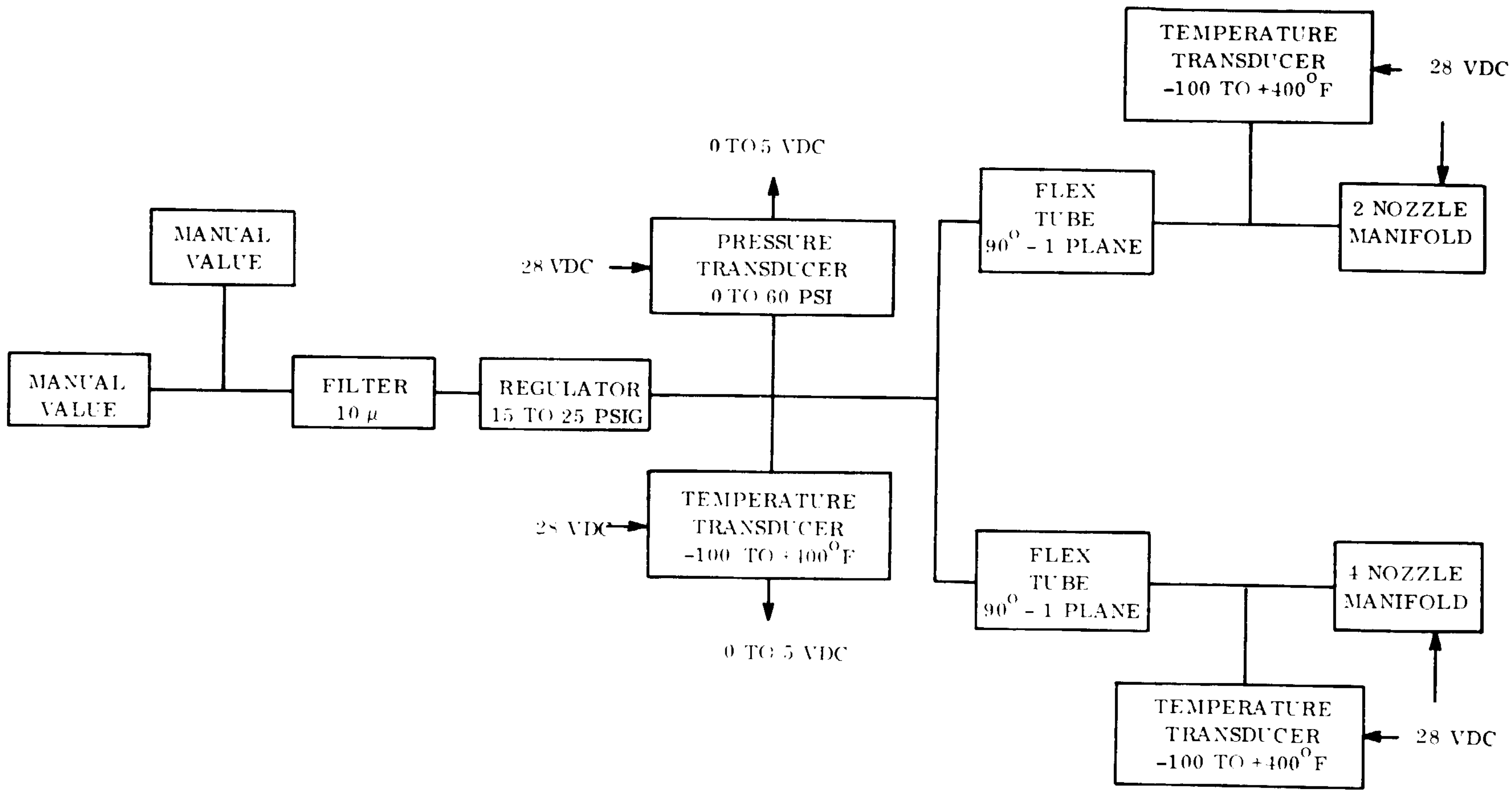


Figure 1-2. Warm Gas Distribution System Block Diagram

The WGDS contains a 10 micron absolute filter to filter the gases prior to entry into the regulator. An adjustable regulator is capable of regulating the gas pressure within the range of 15 to 25 psig. A pressure and temperature transducer are located in the system downstream of the regulator just upstream of a tee which diverts the flow to two jet valve manifolds. Flex tubes are located in each of the two flow paths to permit a 90 degree single-plane deployment of the jet manifolds. One manifold contains two jet valve assemblies while the second has four jet valve assemblies. The jet valve assemblies are customer furnished. Facility type temperature sensor probes are provided in the jet valve manifold assemblies. The system is welded to minimize leakage and has the capability of handling flows up to 96, 000 cc/min with a minimum pressure drop.

SECTION 2

TECHNICAL DISCUSSION

2.1 COMPONENT DESIGN

Detail component design of all WGDS components was completed by the component suppliers during this report period. All GE component source control drawings were updated to reflect the final vendor configurations and released by GE Print Control. Component specifications were also released, which, along with the drawing releases, gave complete configuration control of the components.

The regulator design was changed to incorporate a Belleville spring assembly opposing the main reference helical spring. This change permitted elimination of the friction damping mechanism, and also permitted incorporation of a helical spring design that will provide adjustability over the 15 to 25 psi outlet pressure range with one spring. The overall diameter of the regulator body will be 1.35 inches instead of 1.82 inches, as originally expected.

Design of the jet valve manifolds was revised to incorporate a probe type copper-constantan thermocouple of standard design available from Conax. This design utilizes a pipe thread for connection to the manifold. Although a pipe thread is not normally recommended where extreme cleanliness is required, the manifold design permits total accessibility to the interior of the manifold for cleaning subsequent to the probe installation and prior to the final assembly of the manifold.

2.2 COMPONENT DELIVERIES

The status of component deliveries is discussed in the following paragraphs.

2.2.1 REGULATOR

Delivery of the first unit has been delayed, due to the interference fits of some detail parts discovered during component assembly. Corrective action, consisting of a review of the drawings for tolerance stackups and drafting errors, and reworking of the affected detail parts, was taken. After rework, the unit was successfully assembled and subjected to a preliminary performance test. This test revealed that the Belleville spring rate was too low, resulting in an out-of-specification regulation tolerance. Corrective action for this condition is currently in progress, consisting of redesign and manufacture of a Belleville spring with the correct spring rate. Since the regulator supplier has the capability for producing Belleville springs within his facility, the schedule delay will be minimized. Delivery of the first regulator is now estimated to be 19 January.

2.2.2 FILTER

The filter assembly (see Figure 2-1) was received on 26 December, and is currently in component test. All testing of the unit at the vendor's plant was completed without problems or incidents of any kind.

2.2.3 PRESSURE TRANSDUCER

Delivery of the pressure transducer is delayed, due to the rejection of some detail parts by the component supplier. The affected parts have been re-ordered and are expected by the transducer supplier before 8 January. Delivery of the completed transducer to GE is estimated to be 19 January.

2.2.4 TEMPERATURE PROBES

The temperature probes (thermocouple sensor, Figure 2-2) were delivered 30 October. The probes have been inspected and are ready for installation into the jet valve manifolds.

2.2.5 SURFACE TEMPERATURE SENSOR

Delivery of the surface temperature sensor (platinum resistance element) is delayed, due to problems with the signal conditioner package. These problems have been resolved and the unit has passed acceptance testing and will be shipped 8 January.

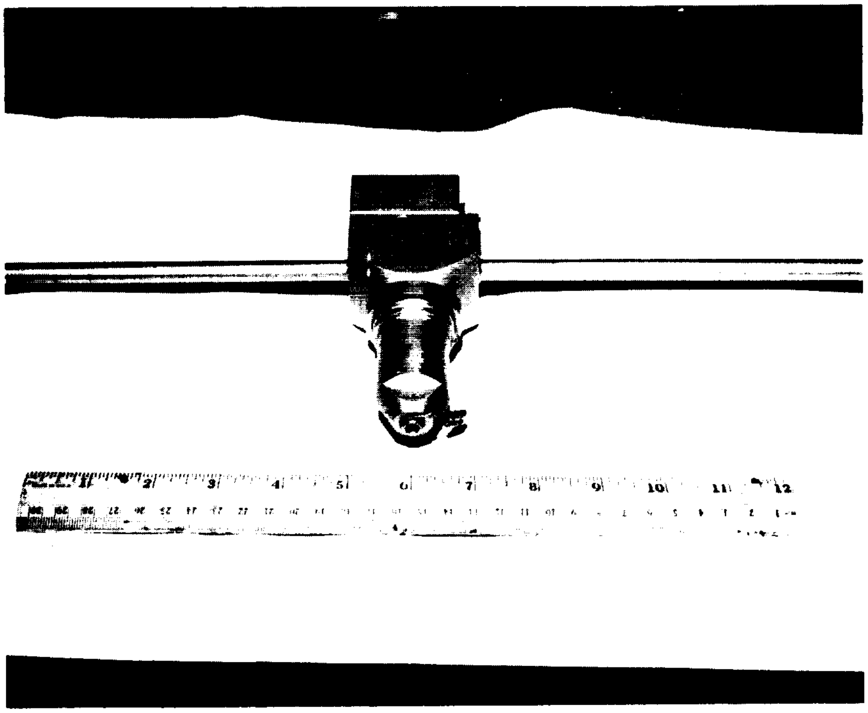


Figure 2-1. Filter Assembly

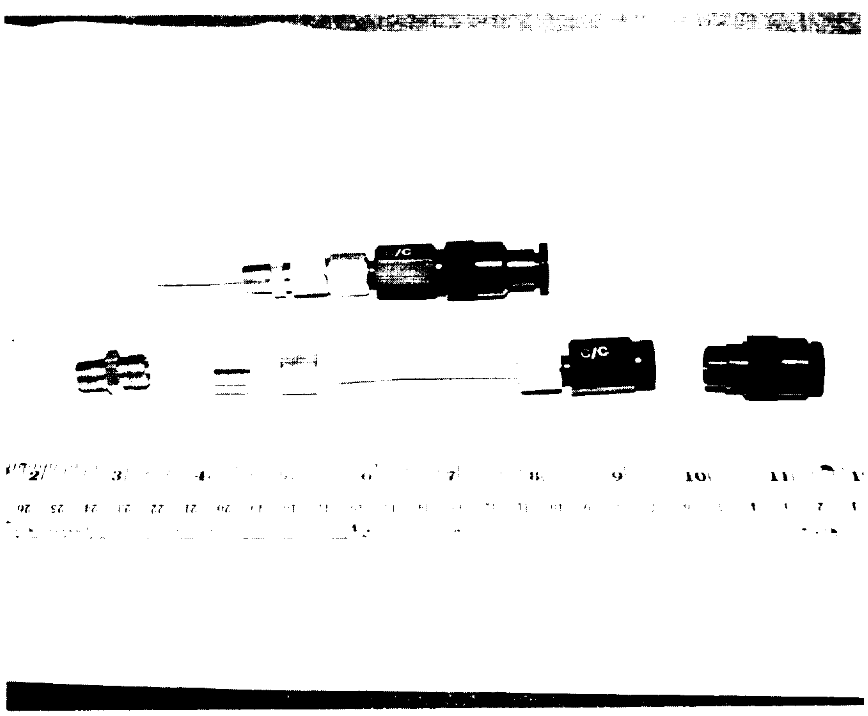


Figure 2-2. Copper-Constantan Thermocouple Probe

2.2.6 HAND VALVES

The hand valves (see Figure 2-3) were delivered to GE on 21 December and have completed component tests. Contamination checks run on the three hand valves demonstrated cleanliness levels better than 25 microns absolute, demonstrating that the special assembly procedure followed by Nupro and GE was successful.

2.2.7 FLEXIBLE HOSE

Delivery of the flexible hose has been delayed, due to a lengthy strike at the supplier's Eastern facility. The local representative is taking steps to fill the order from their West Coast plant. The West Coast plant has all the necessary material on hand to fabricate the required pieces and has estimated that the hose will be shipped to GE on 22 January.

2.2.8 MANIFOLDS

Raw materials for fabrication of the manifolds have been received by GE. Machining of the manifolds will start 8 January and the completed assemblies, including welding and cleaning operations, are expected to be available by 19 January.

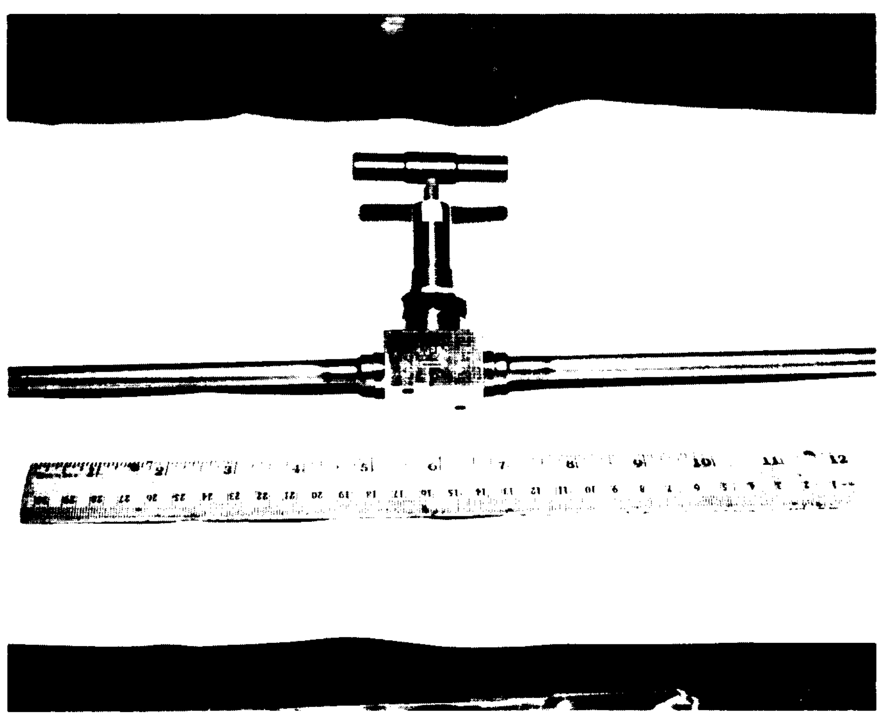


Figure 2-3. Hand Valve (Purge and Prepressurization Valve)

2.2.9 SOLENOID VALVES

Solenoid valves for the Warm Gas Distribution System are supplied by the customer as GFE. Delivery of the valves to GE for assembly into the system is expected to be compatible with the WGDS schedule.

2.3 COMPONENT TEST RESULTS

Tests have been conducted on some of the WGDS components by suppliers during this report period. These components include the regulator, filter, surface temperature sensor, and hand valves.

2.3.1 REGULATOR

The first regulator (two are on order) was assembled and subjected to ambient functional tests by the supplier. The regulator operated out of tolerance by approximately 0.2 psi (total regulation tolerance of ± 0.6 psi). Cause of this condition was determined to be an excessively low spring rate for the Belleville spring. The low rate did not provide enough negative spring rate with respect to the positive rate helical spring. The test did show, however, that the Belleville spring does contribute enough friction to accomplish the required damping, thus assuring elimination of the initial slip ring damper mechanism design.

2.3.2 FILTER

Acceptance testing of the filter assembly was successfully completed at the vendor's plant, consisting of visual examination, bubble point, ΔP indicator check, proof pressure, external leakage, flow, and cleanliness check. The bubble point was measured at 13.9 inches of water, which correlates to better than a 10 micron absolute rating for the etched disc type filter element. External leakage was 1×10^{-8} scc/sec Helium at 200 psig, and the pressure drop did not exceed 0.15 psi at maximum flowrate. The cleanliness check revealed no particles larger than 25 micron in size from a 100 mm flush sample.

2.3.3 SURFACE TEMPERATURE SENSOR

The surface temperature sensor and mating signal conditioning equipment have been successfully tested at the vendor's plant. Initial problems in matching the amplifier to the platinum resistance element have been overcome, and the necessary calibration curves generated.

2.3.4 HAND VALVES

Following final assembly at the vendor's plant, the hand valves (3) were subjected to proof pressure, internal and external leakage tests, successfully completing the tests. At GE, the valves have been subjected to physical examination, proof pressure, static leakage (internal and external), pressure drop, and contamination check. All valves were proof tested at 300 psig with no evidence of damage or degradation. Leakage test results for the three valves are:

Unit	Seat Leakage (He)	Body Leakage (He)
1	5.83×10^{-3} scc/hr	3.4×10^{-6} scc/hr
2	0.337 scc/hr	4.8×10^{-6} scc/hr
3	0.051 scc/hr	3.2×10^{-6} scc/hr

Pressure drop at 96,000 scc/min GN_2 flow was 0.2 psi, 0.17 psi, and 0.15 for units 1, 2 and 3 respectively. Contamination checks of all three valves revealed no particles larger than 25 microns.

2.4 CONTAMINATION CONTROL

Contamination control procedures being carried out by GE are designed to meet the 25 micron absolute system contamination control requirements of the WGDS. These requirements led to a search for separable connector fittings for the components which would permit component test and preliminary system assembly and disassembly without degrading the initial contamination levels. Most available commercial fittings include screw threads which are contaminant generators. The problem was further aggravated by the welded design of the WGDS, which required tube stubs on components and the installation of temporary fittings for component testing. A design approach to the problem was evolved, and a special fitting was designed and tested. (See Figures 2-4 and 2-5.) This fitting uses an O-ring seal between flat faces clamped together by an external split ring clamp. The fitting is welded to the tube, with final machining of the flat face accomplished after the tube to fitting weld operation. Tube stubs with these special fittings have been furnished to all WGDS component suppliers for welding to the component bodies.

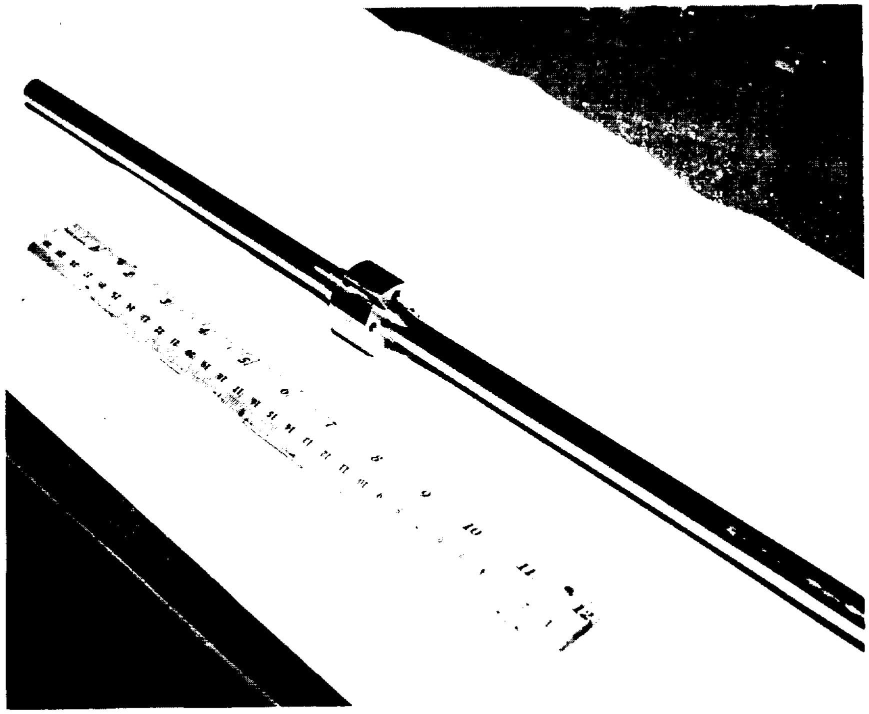


Figure 2-4. Assembled Test Fitting

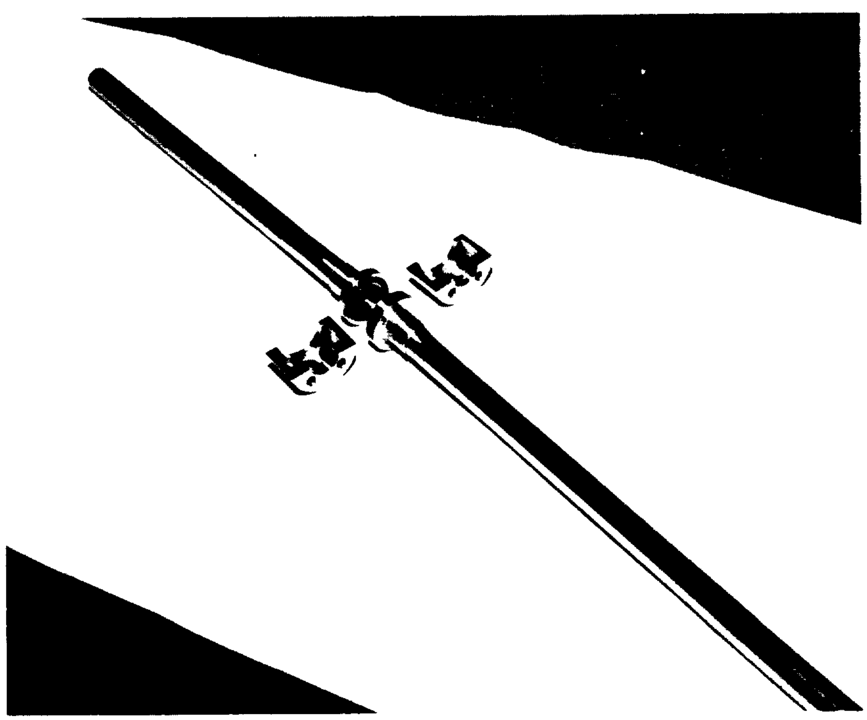


Figure 2-5. Disassembled Test Fitting

All tubing used in the WGDS will be the ultrasonically drawn type, which gives a superior surface finish inside the tube. This improved surface finish enhances cleanability of the tubing and improves the effectiveness of subsequent cleaning or purging operations. In addition to being ultrasonically drawn, all tubing for the WGDS will be electropolished, which will result in further improvement of the tube surface. Tubing shown in component photographs, Figures 2-1 and 2-3, 2-4, have been electropolished.

Close attention to contamination control problems was also required in the case of the hand valves, when it was found during the procurement cycle, that the supplier would be unable to meet the required cleanliness level. Despite a purchase order based on a drawing which called for 25 micron absolute contamination control being accepted, follow-up by GE determined that the supplier could not meet this requirement due to facility limitations. GE evolved a manufacture and control technique for the hand valves which produced the necessary cleanliness level. This technique required the supplier to ship the partially assembled valves to GE for cleaning, assembly of internal parts, and clean packaging. This has been accomplished with the parts cleaned to better than 25 micron absolute. Cleanliness of internal passages was protected by filters installed at the inlet and outlet tube stubs. The valves were then returned to the vendor for the final closure (external) weld, which could be accomplished without violation of the clean interior passages of the valves. These valves have been returned to GE and have completed acceptance test, which included a contamination check. Cleanliness of the valves was maintained at better than 25 micron absolute during the above procedures, as shown by particle count.

2.5 SYSTEM FABRICATION

Fabrication of the handling structure, including the articulating arms and panel, is complete (Figure 2-6). As a final step, the entire assembly will be electropolished. This will improve appearance and cleanability of the structure. Cleaning of the structure is required, since it will be located in a clean environment during some stages of system assembly.

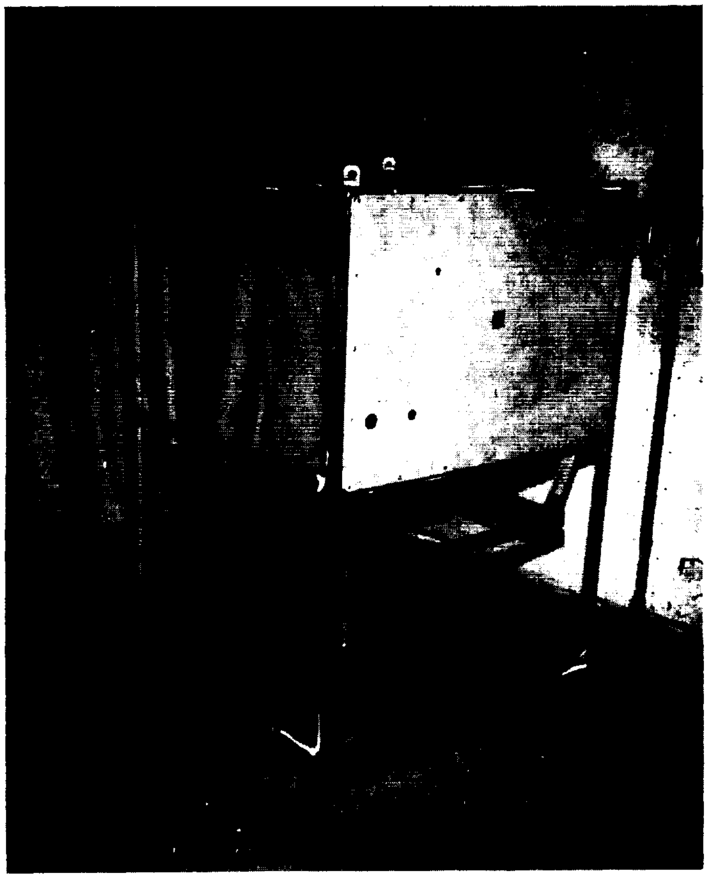


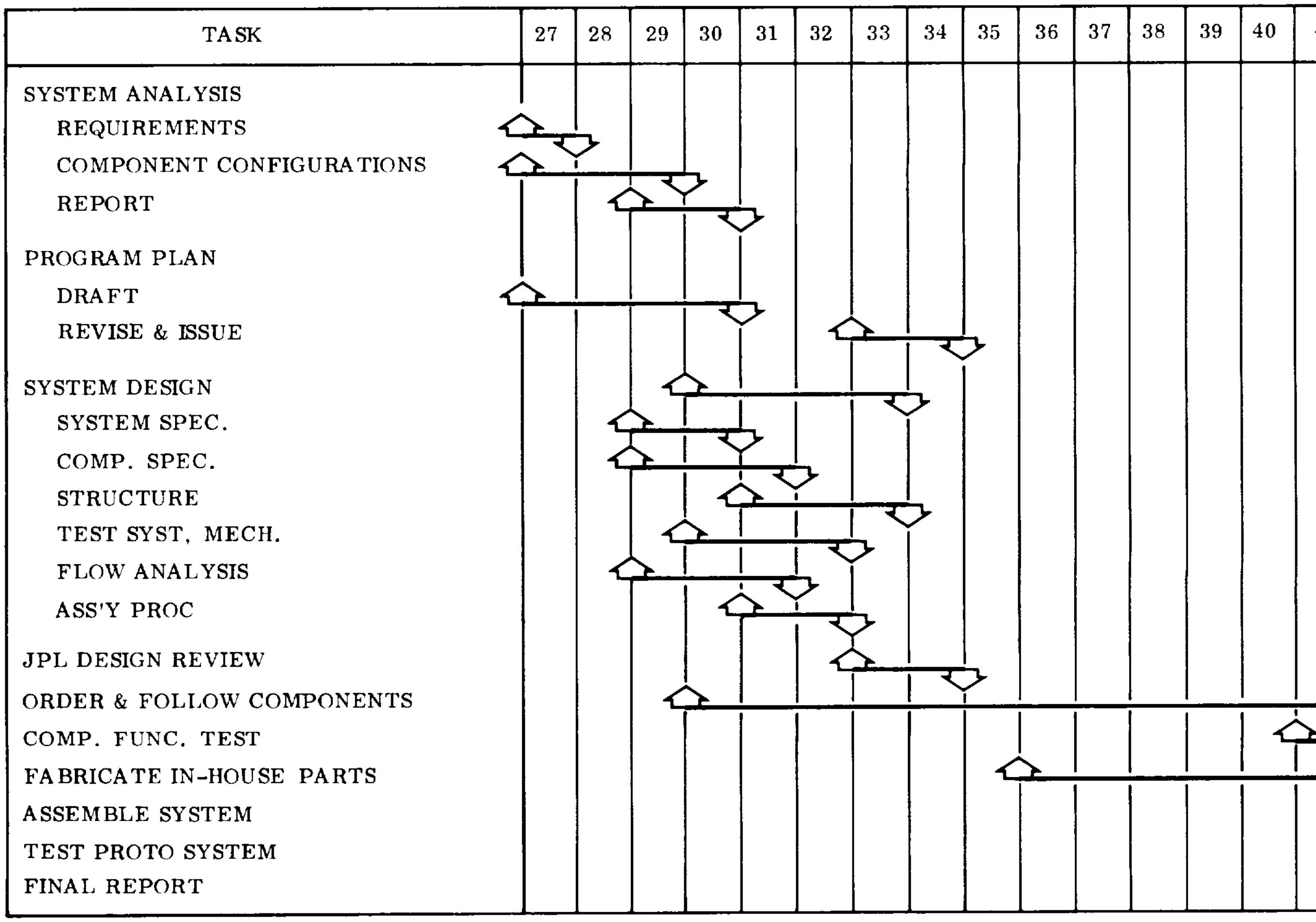
Figure 2-6. Handling Structure

No system assembly has been initiated since all components have not been received. However, all necessary tubing and weld sleeves are in house. The weld sleeves will be cut from lengths of ultrasonically drawn tubing, which were drawn at the same time and from the same material as the system tubing. The sleeve tubing was drawn slightly larger than the system tubing and sized to provide a close tolerance fit between the tubing and the welding sleeve. These consistent fits will make the welding process easier, repeatable, and more reliable.

2.6 WORK TO BE COMPLETED DURING NEXT REPORT PERIOD

A revised program schedule reflecting the effect of slippage in component delivery dates is shown in Figure 2-7. Current information, as of the present reporting period, indicates that the surface temperature sensor and amplifier will be delivered on or about January 12, the regulator on or about January 19, and the pressure transducer on or about January 19. The JPL customer-supplied solenoid valves are estimated by JPL to become available on or about January 24. The schedules for completion of component test and system assembly are, therefore, keyed to the availability of the solenoid valves, although other system assembly activities will be completed prior to installation of the valves. It is now estimated that system testing will be completed on or about March 8, 1968, with the final program report to be submitted on or about March 29, 1968.

GE FIS


TASK
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SYSTEM ANALYSIS
REQUIREMENTS
COMPONENT CONFIGURATIONS
REPORT
PROGRAM PLAN
DRAFT
REVISE & ISSUE
SYSTEM DESIGN
SYSTEM SPEC.
COMP. SPEC.
STRUCTURE
TEST SYST. MECH.
FLOW ANALYSIS
ASS'Y PROC
JPL DESIGN REVIEW
ORDER & FOLLOW COMPONENTS
COMP. FUNC. TEST
FABRICATE IN-HOUSE PARTS
ASSEMBLE SYSTEM
TEST PROTO SYSTEM
FINAL REPORT

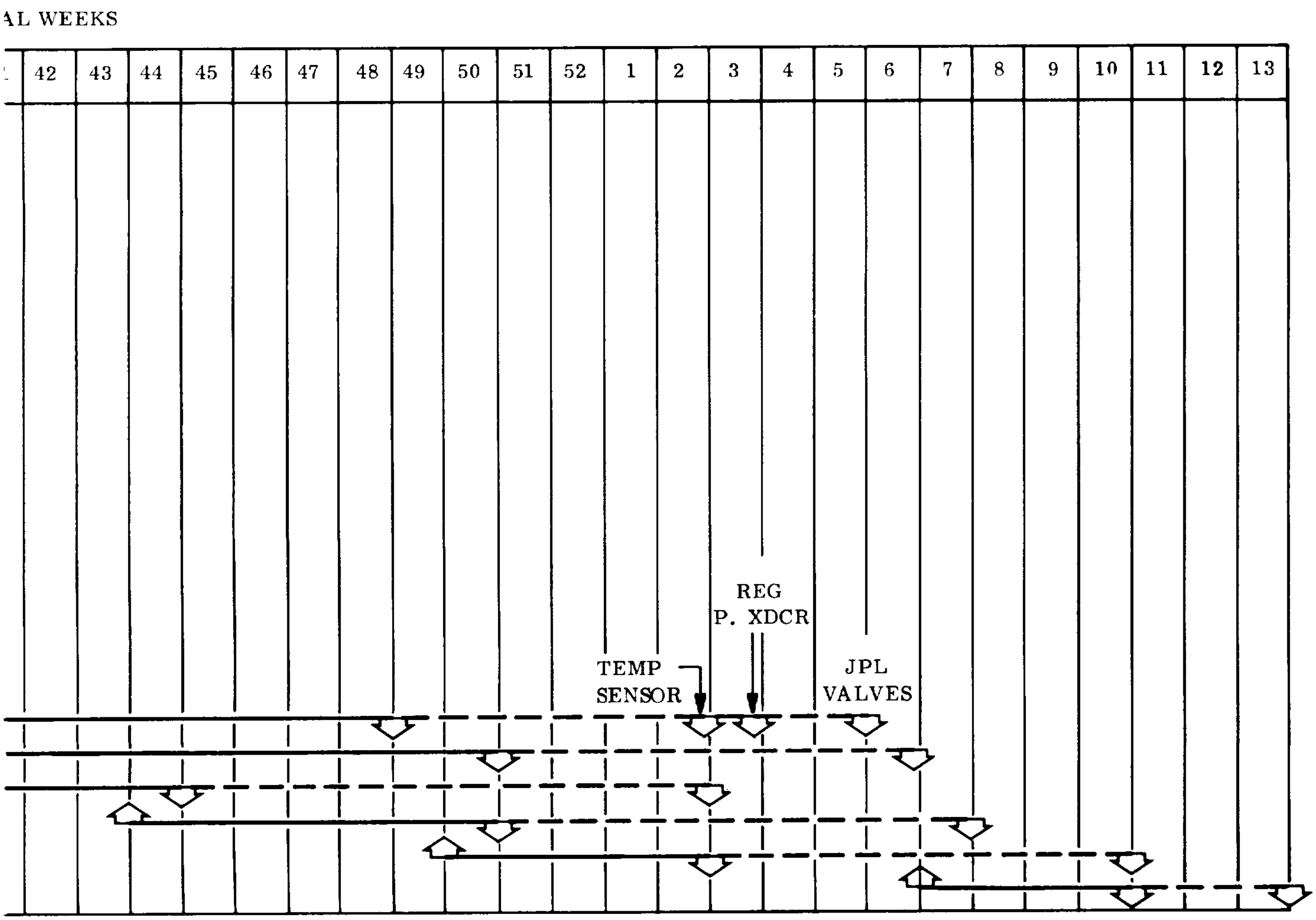

Figure 2-7. Warm Gas Distribution System Program Schedule (Revised)

SECTION 3
CONCLUSIONS

The Warm Gas Distribution System Program is proceeding toward system assembly and demonstration. No unusual or insoluble problems have been encountered to date. Certain of the contamination control procedures followed in the performance of work to date and/or to be observed during the remainder of the program show excellent promise of useful application to all future pneumatic systems. These include use of electropolished tubing, contamination sealed manifolds, and non-contaminating test fittings.

SECTION 4

NEW TECHNOLOGY

No reportable items of new technology occurred during this reporting period.